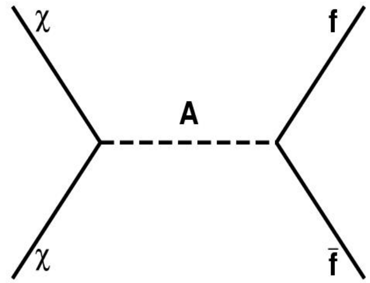
Indirect dark matter search: Cosmic positron spectrum measurement from 1 to 50 GeV with AMS-01

For the AMS Collaboration:
Henning Gast,
J. Olzem, St. Schael
RWTH Aachen

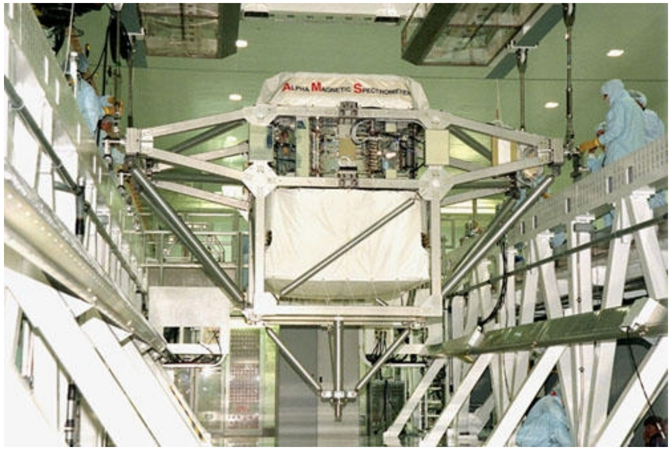
DPG-Tagung
Dortmund
30. März 2006

Overview

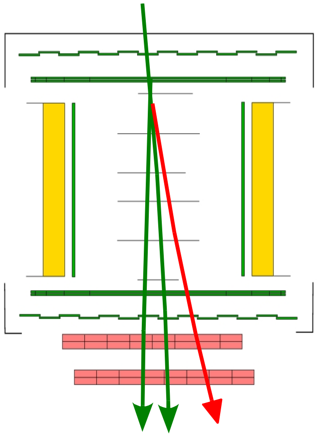
- Motivation: Indirect search for neutralino dark matter



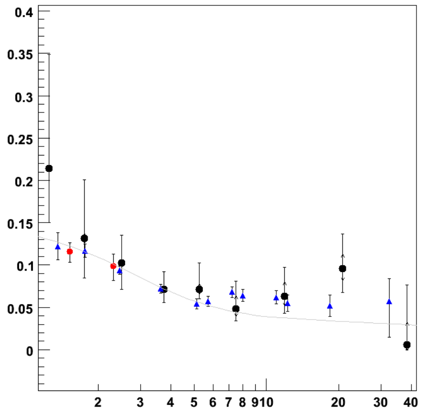
- The AMS-01 detector



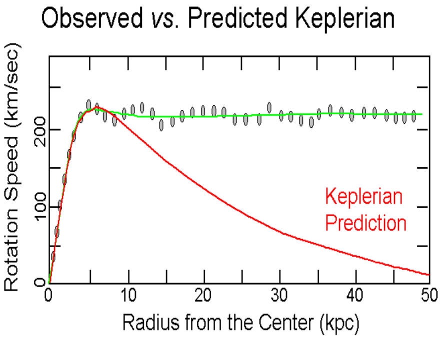
- Positron identification with AMS-01 using bremsstrahlung events



- Positron fraction result



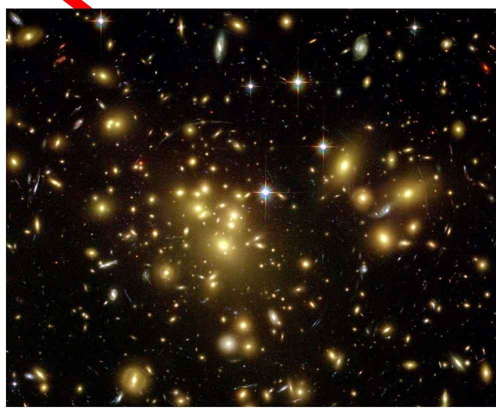
Motivation: Indirect Dark Matter Search



R.Pogge

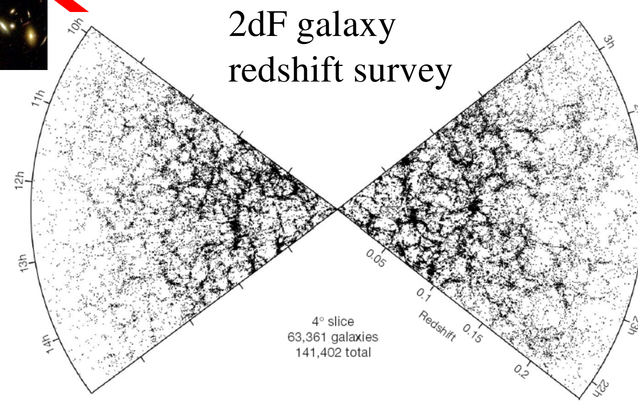
Rotation curves of spiral galaxies

on all cosmological scales



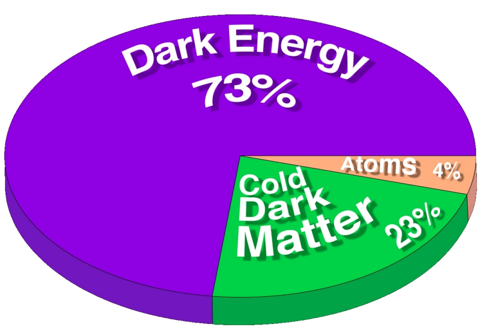
Abell 1689, HST

Clusters of galaxies:
- peculiar velocities
- x-ray emissions of the hot gas
- weak gravitational lensing



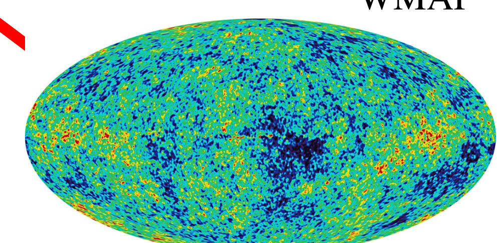
2dF galaxy redshift survey

Large-scale structure of the universe



Anisotropy of the Cosmic Microwave Background

WMAP



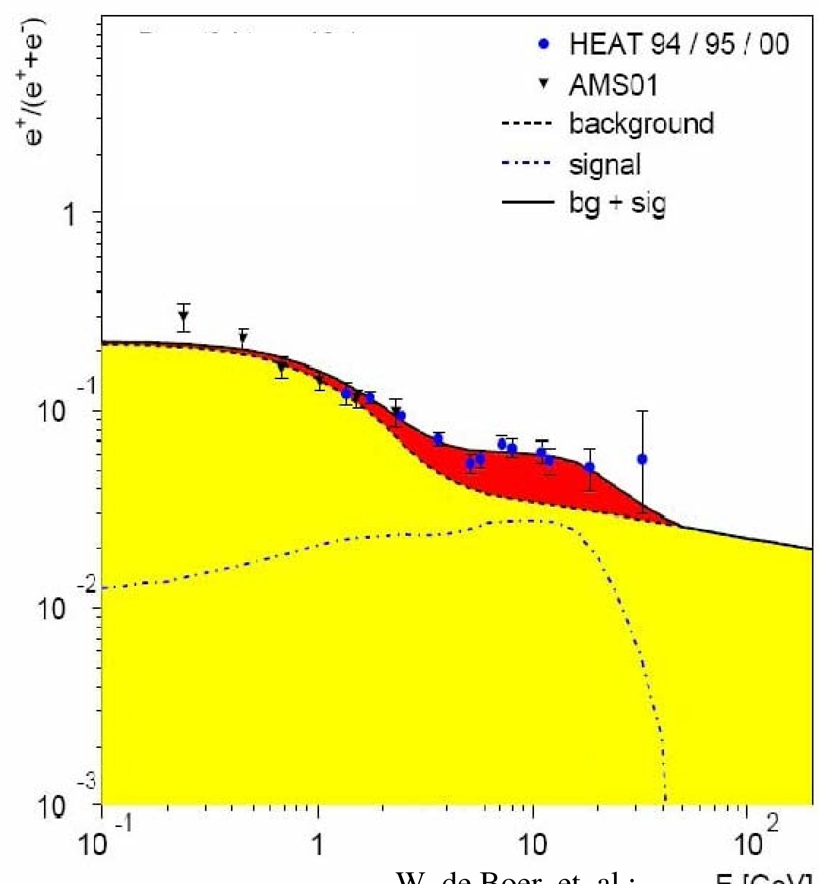
Candidate: SUSY-Neutralino

New particle?
- stable
- only weak interaction with "normal" matter

Properties of the **Neutralino** χ appearing in certain SUSY theories

Scenario: SUSY with R-Parity conservation (2 SUSY fields at the vertex)
$\Rightarrow$ LSP is stable
If it is neutral
$\Rightarrow$ only weak elastic scattering with normal matter

Annihilations occur:
$\chi\chi \rightarrow l^+l^-, W^+W^-, q\bar{q}, \ldots$

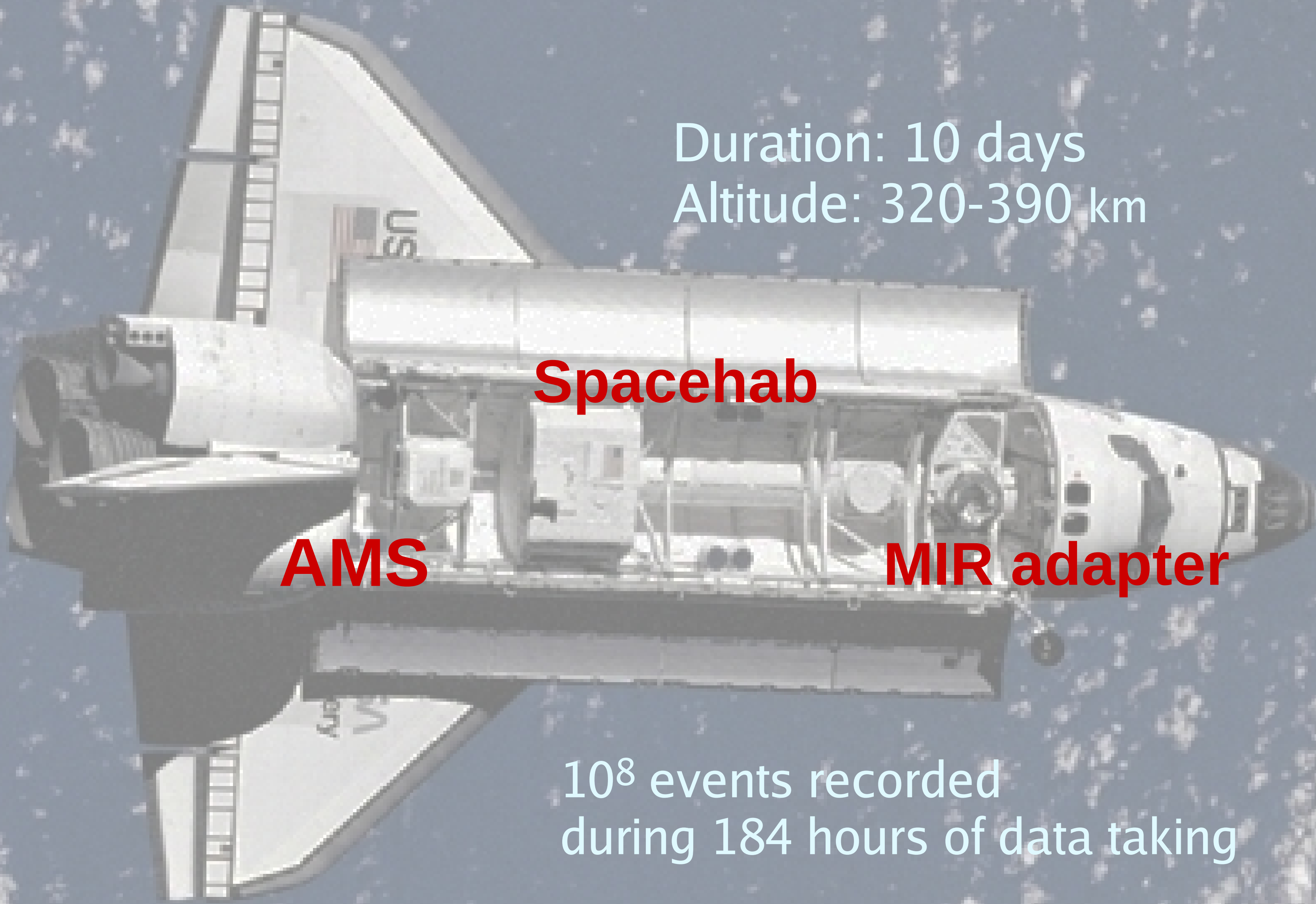


W. de Boer et al.:
Talk at Graduate School, Tübingen, 10 Feb 06
"Supersymmetry and dark matter"

⇨ primary source of positrons
⇨ flux of secondary positrons must be known

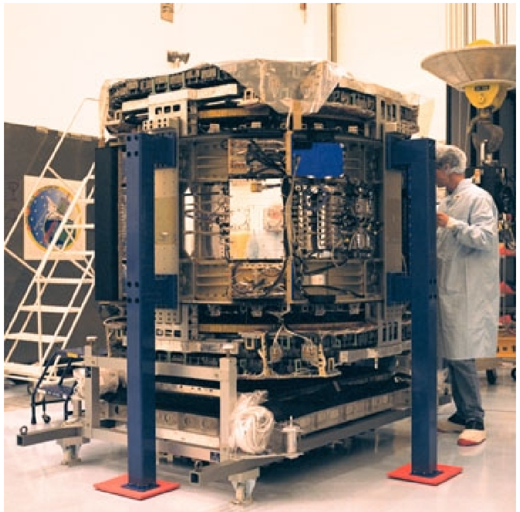
STS-91 Discovery in June 1998

Duration: 10 days
Altitude: 320-390 km



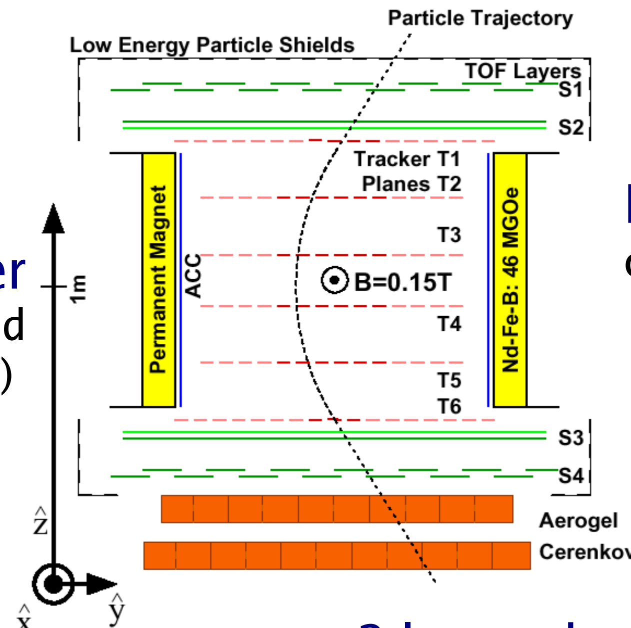
10^8 events recorded
during 184 hours of data taking

The AMS-01 experiment



Alpha Magnetic Spectrometer

Particle spectrometer in space as a prototype for the AMS-02 experiment on the ISS



2 double layers of scintillators (TOF)

fast trigger, measuring β, flight direction and charge number

Permanent magnet

cylindrical dipole, 0.15 T

Silicon tracker

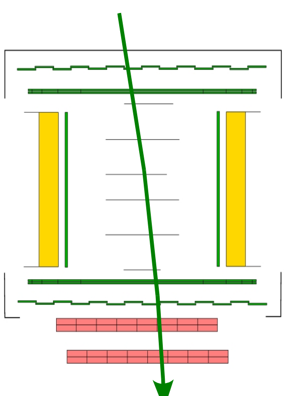
6 analog layers of double-sided silicon for tracking and dE/dx (Z > 1)

Anticounter scintillators

veto against lateral tracks

2 layered aerogel čerenkov counter

measuring β, **e/p separation up to 3 GeV**

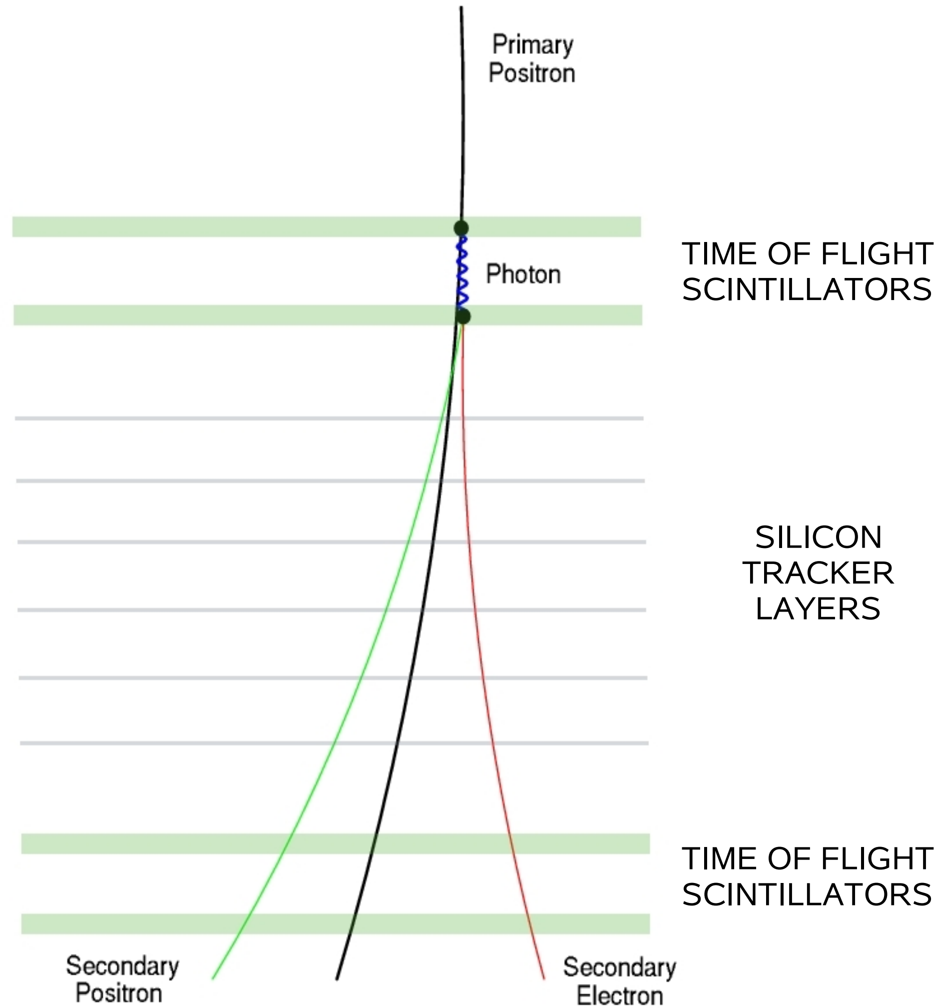


Single tracks:

measurement up to the čerenkov limit (3 GeV)

Signature of converted bremsstrahlung

- Primary e^+, e^- radiate bremsstrahlung γ
- γ converts to e^+e^- pair

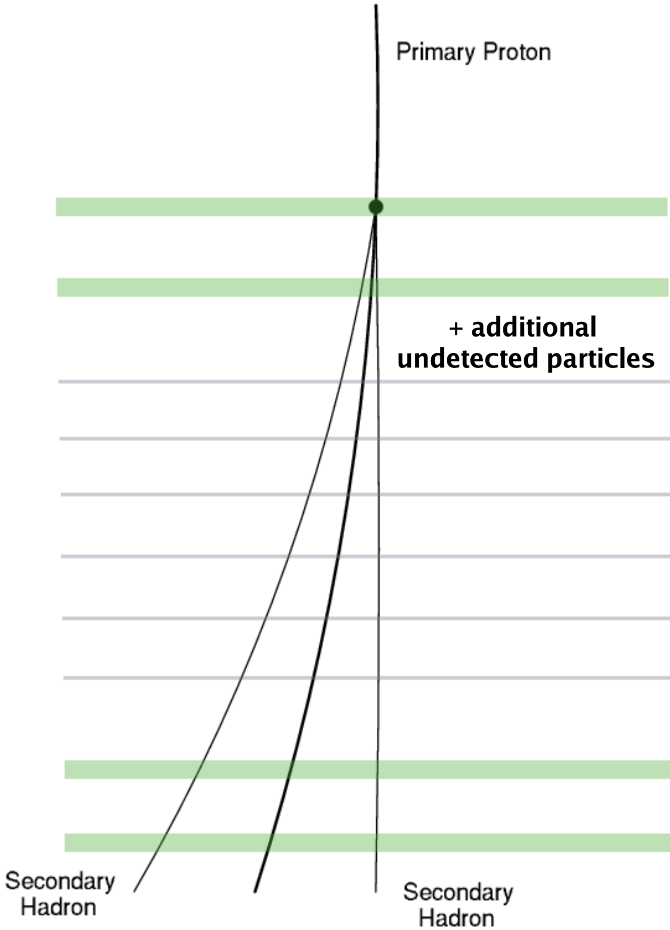


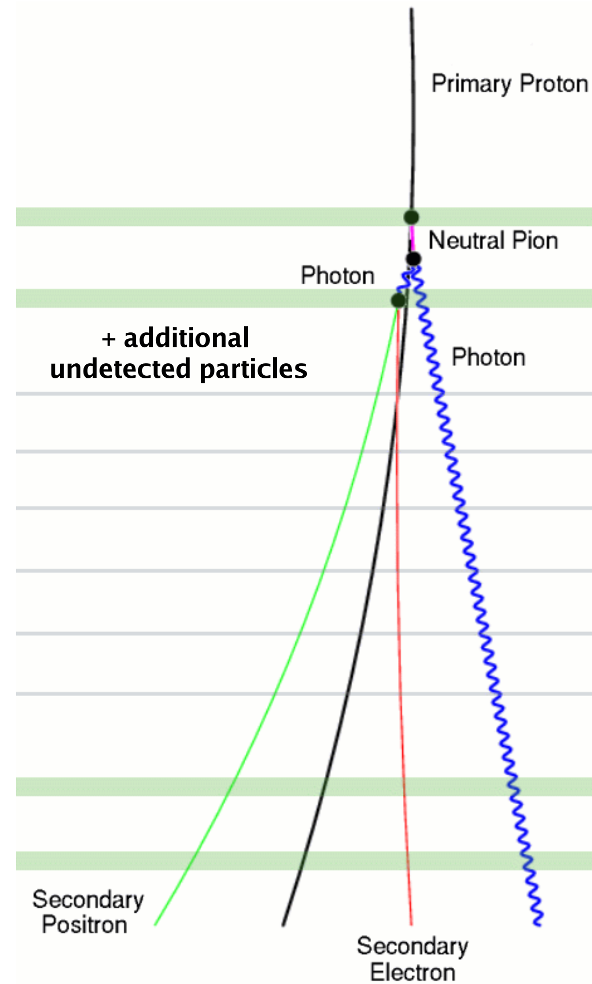
3 track signature, middle track is primary in >90% of events due to higher momentum

Small opening angles at vertices ($\propto \gamma^{-1} \approx 0$)

Bremsstrahlung yields "built-in" proton rejection by a factor of 10^6 ($\sigma \propto 1/m^2$)

Dominant background





charged pion production

$p+p \rightarrow p+p+\pi^{+}+\pi^{-}\ (+X)$

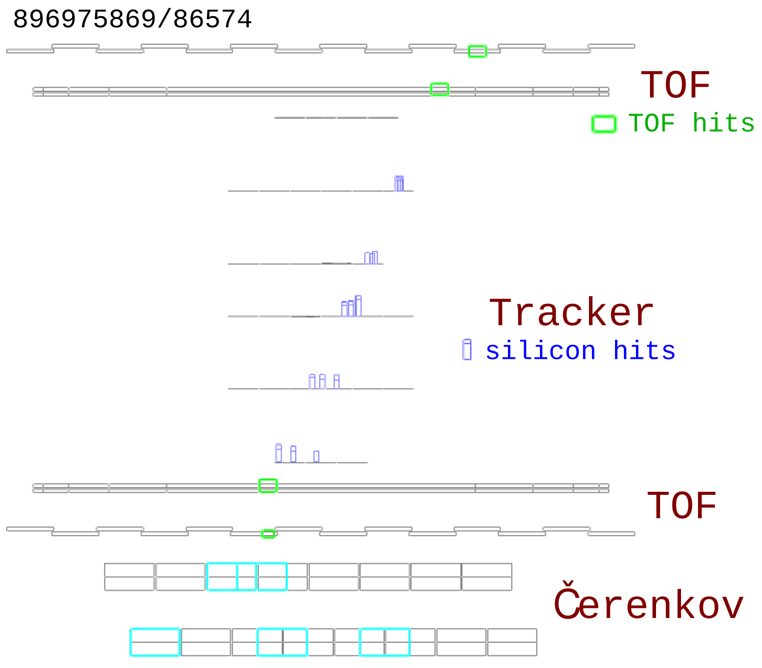
neutral pion decay

$p+p \rightarrow p+p+\pi^{0}\ (+X)$

$\hookrightarrow \gamma\gamma \rightarrow \gamma\, e^{+}\, e^{-}$

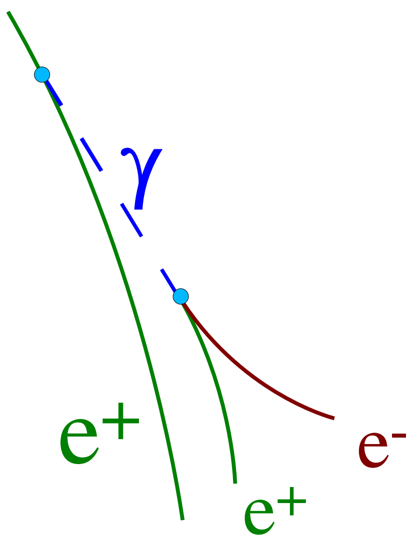
+ electrons with wrong momentum sign

Event reconstruction



Seedless combinatorial track finding

- build 3 tracks from silicon hits
- use constraints on track charge
- cut on flight time, dE/dx in silicon
- eliminate atmospheric secondaries by individual backtracing

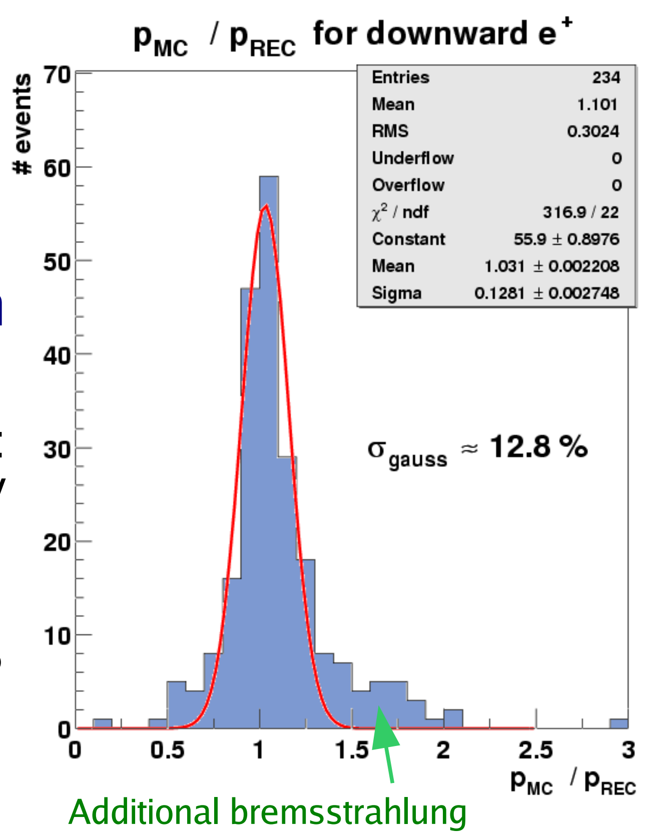


Total momentum resolution (sum of 3 tracks) ≈ **13%**

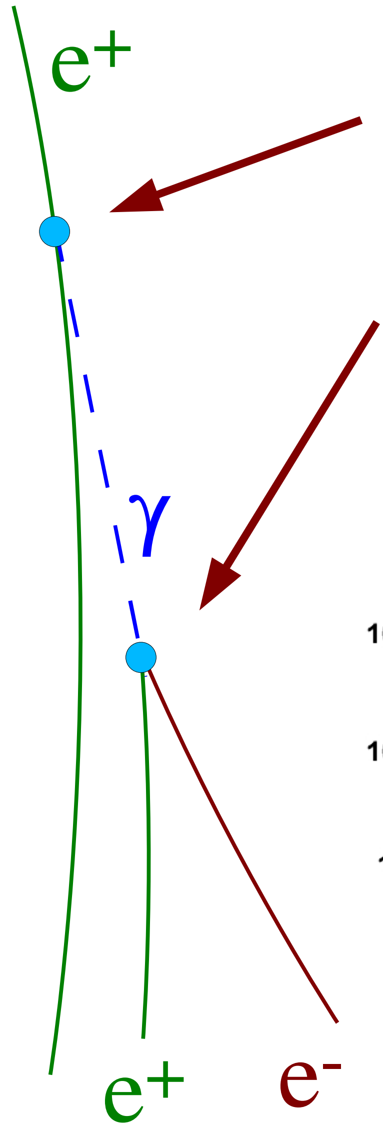
- AMS-01 single track: ≥ 12 % > 10 GeV

Photon:

- Momentum resolution ≈ **8%**
- Absolute direction error ≈ **0.01 rad**

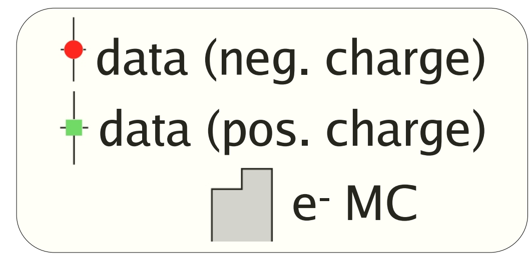


Background suppression

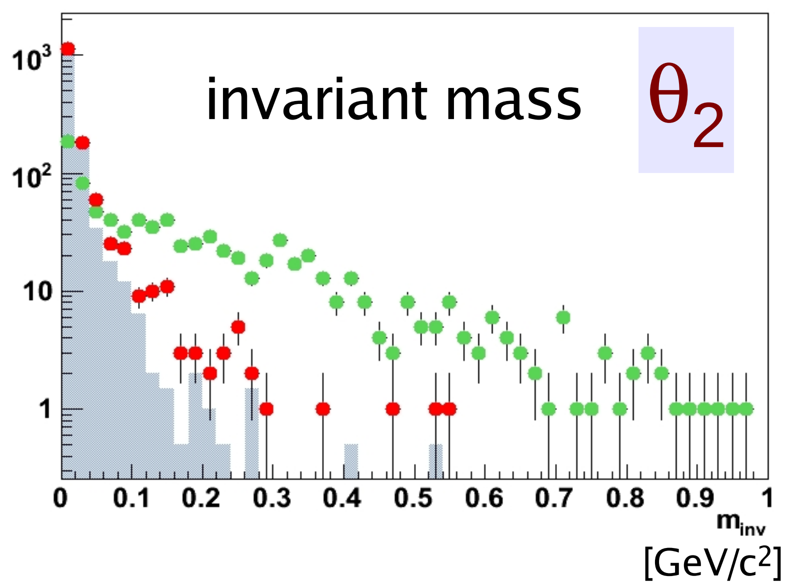


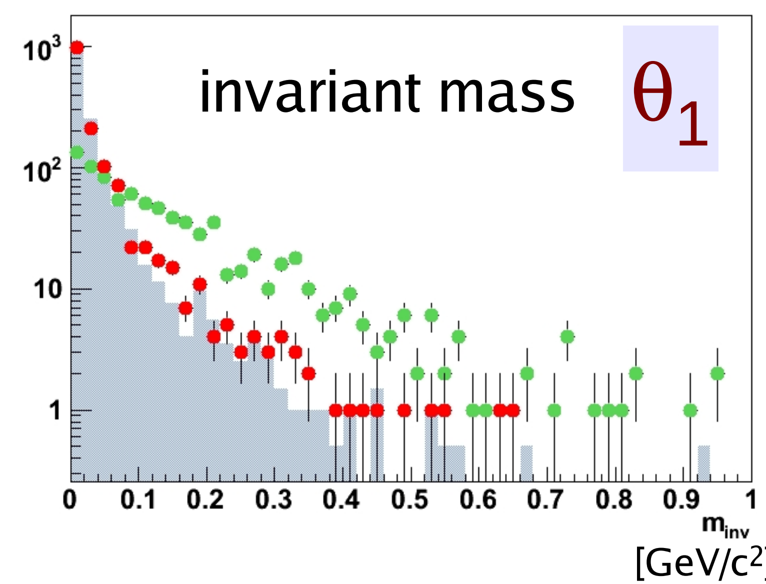
θ_1 Angle of reconstructed photon and primary
($\theta_1 \approx 0$ for Bremsstrahlung)

θ_2 Angle of secondaries
($\theta_2 \approx 0$ for photon conversion)

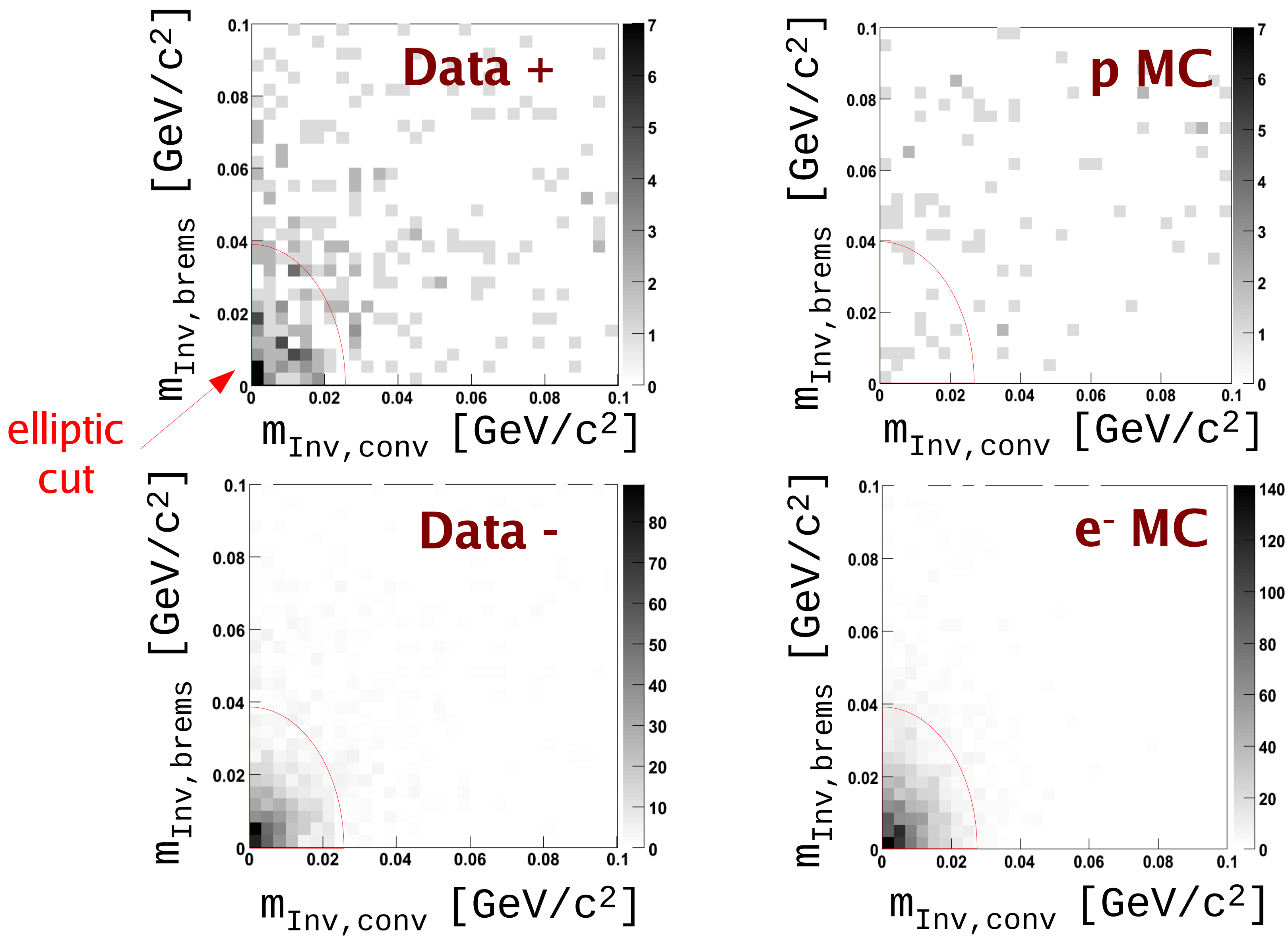


Use **invariant masses** at vertices
to make angles independent of reference frame





Background suppression



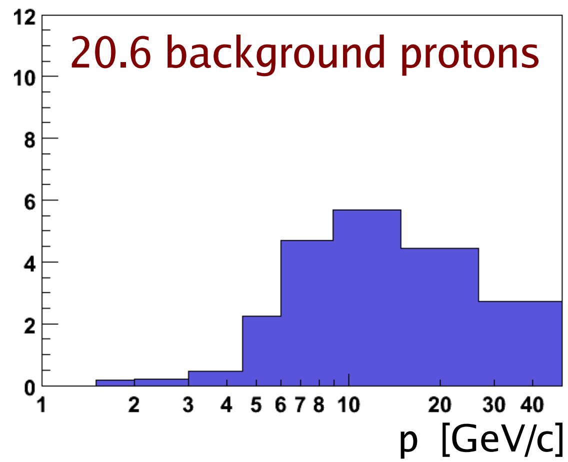
Correction of irreducible background

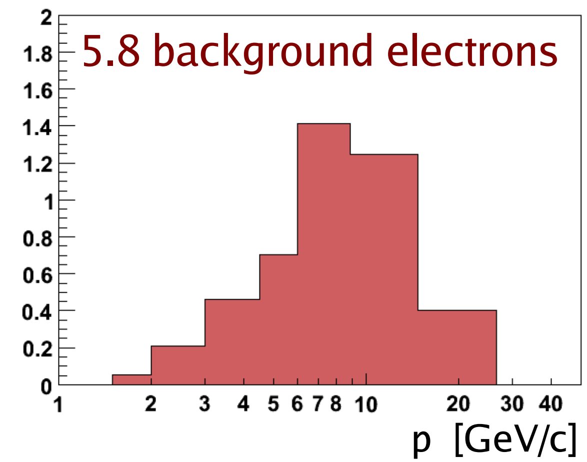
Background correction from Monte Carlo:

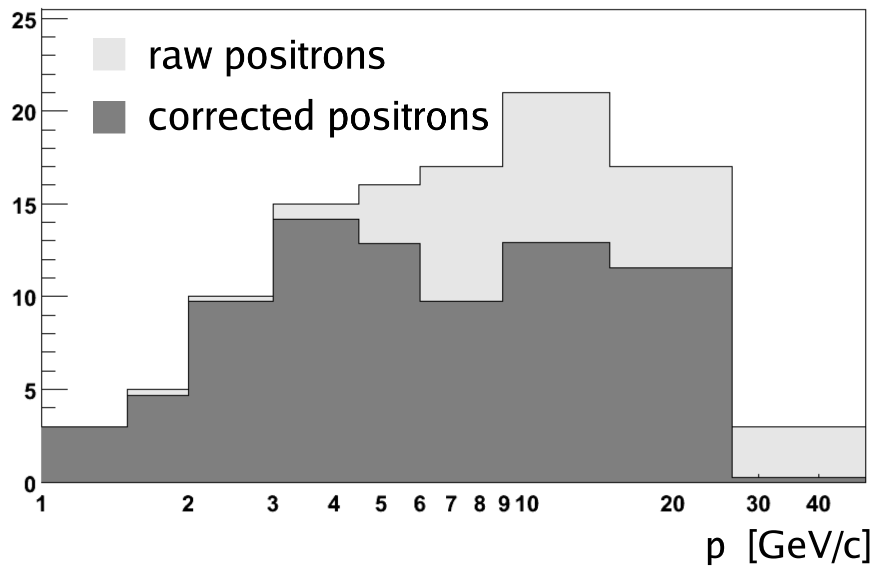
Consider:

- Accurate scaling to data
- Geomagnetic field effects
- Energy spectrum

106 positron candidates in total





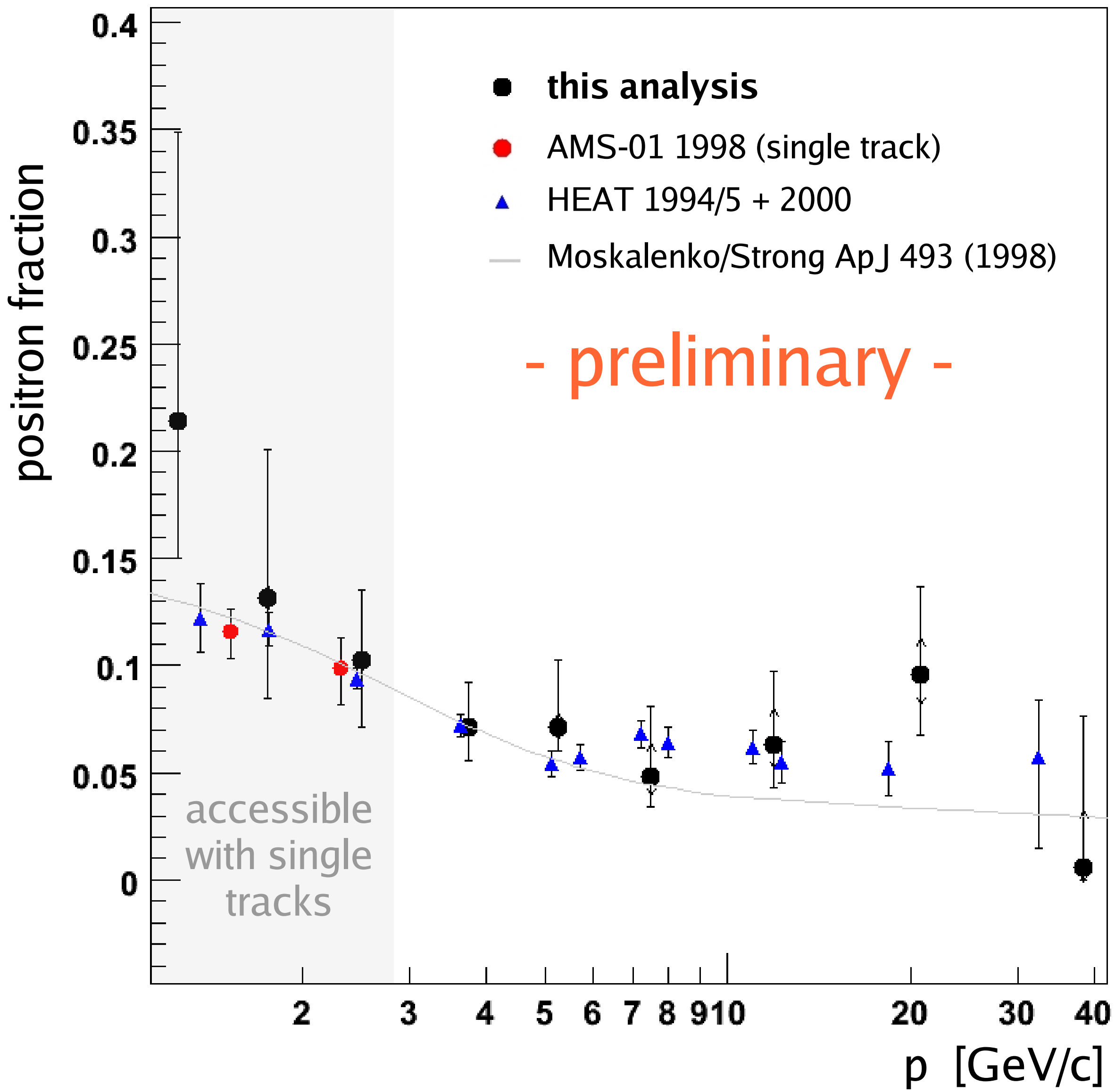


Total correction:

≈23% of the positron candidates

Background peaks outside signal region

Positron fraction



Statistics:

79 (106) e+
1015 e-

Above 10 GeV:

- 26 positrons
- HEAT-$\bar{p}$ (2000): 35 positrons

Further refinement of background correction

with more MC statistics

Conclusions

The AMS-01 detector is very well understood.

Positron identification through converted bremsstrahlung.
- Extension of the accessible energy range far beyond the design limits
- Full exhaustion of the detector's capabilities

Level of disagreement with positron background is under study.

The AMS-02 experiment to be installed on the ISS will conduct cosmic-ray spectroscopy with unprecedented precision.
- Indirect dark matter search: positron, antiproton, gamma channels
- Look for cosmic antimatter (anti-He)
- Test propagation models ($^{10}Be/^{9}Be$, B/C)